**ORACLES P3 Flight Scientist Post-Flight Status Report**

Date: ___05 October 2018_____

Flight number: ____PRF05Y18_____

Routine flight or target of opportunity? ____Target_____

If target of opportunity, what is the goal? __Radiation in partly cloudy skies at high solar zenith angles for 4STAR almucantar scans_____

Flight scientist: _____ Sarah Doherty _____

Assistant flight scientist: _____n/a_____

Ground scientist: _____ Jens Redemann _____

Asst. Ground scientist: _____Michael Diamond_____

Take-off: _____04:05UT_____

Landing: _____12:54UT_____

Quick summary:

Representative ACAOD or ACAOD range for flight: 0.3 ACAOD, 0.4 full-column

Do the models predict crossing a gradient in aerosol age? YES (older in boundary layer, younger above)
Yes/No/Unclear
Notes: some gradient in age with youngest plume towards Southern edge of plume (routine flight is back-up option).

Did the flight cross a gradient in macroscopic cloud properties, like cloud fraction?
Yes/No/Unclear
Notes: Radiation work centered over a significant local minimum in low cloud fraction

Did the flight cross a gradient in aerosol loading?
Yes/No/Unclear
YES while in-transit N-S on 5E; NO significant gradient in aerosol loading/AOD across extent of radiation wall.

At any point during the flight, was there a clear separation between the smoke plume(s) and cloud tops?

Yes/No/Unclear
PROBABLY at the north end of the 5E transit; but in radiation wall, pollution reached down into BL

How many of the following maneuvers took place?

Ramps _0_____

Square spirals ___2_____

MBL legs __2_____

Cloud legs _one during radiation wall,

one more during transit

home_____

Above cloud legs __ 3_____

Sawtooth legs __0_____

Plume legs __>3_____

Above plume legs __outbound transit

from TMS to 9S and towards wall location;

2 full overpasses of radiation wall area; on

the return from 6.5S to EREGO

Instrument status:

| Instrument | Comments |
|---|---|
| P3 | No problems. |
| 4STAR | All good. AOD ~0.3-0.32. Some likely window dep again. Also got good morning portion for calibration. |
| HiGEAR | Had a rough start because TDMA not happy. Tested to see if they got 30-40nm particles in clouds and looks like answer is yes. Also did what might be a refractive index measurement from TDMA to USHAS. |
| HiGEAR-AMS | Worked great. Got some really great data from all the in-situ work. Really excited about the cloud work behind CVI because really polluted. Also most polluted BL this year. |
| HSRL-2 | Good flight. Instrument worked well again. Lots of interesting aerosol structure. Could see all the way down to the surface which was not the case on other flights. Saw an interesting structure in the upper troposphere that in-situ instruments also saw. |
| PTI | Performed well. Getting ~0.85-0.87 for SSA but that's very preliminary. |
| RSP | Instrument worked well. Got data before 1st square spiral. Then little bits of stuff here and there but not above all aerosol so will do cloud only. On high altitude leg home it's not clear if they'll be able to get anything due to roll oscillations in auto-pilot mode. Worked with the pilots en route home to find an autopilot mode setting that minimized these oscillations.<br><br>The sun was very low when did first leg, and they really need SZA>20deg. But we were flying in the principle plane so best they could do for low sun. |
| APR3 | Very good day because they got interesting precip on transit south and precip in the radiation wall. In the clear sky spiral they fine-tuned performance in signal which will allow them to run the radar with even better performance going forward. |
| Cloud probes | Things were pretty swell today! Great mixing in the clouds that will be cool to look at. |
| CCN | Worked well. Very excited about MBL being very different from earlier flights. |
| PDI | Worked well. Showed bimodal distributions and had large and small droplet counts and no interference. |
| Vertical winds | As far as we know, all good (no one on the plane for winds). |

| | |
|---|---|
| WISPR/CVI | Today was mixed. CVI worked great. One of the isotope instruments was dead today so can't get data from the clouds. 2nd instrument he has to replace this one is good only up to ~5,000', but we'd have that.<br><br>(Note: primary instrument was later fixed!) |
| COMA | Good flight. Everything worked well. Saw higher than usual CO in the BL and in the clouds in the radiation wall. |
| SSFR | Worked well for most of flight. So did SPN and the camera. Had two 9-rated spirals and after radiation work. Did some tests w/ the platform & it's still not coming up in limit mode, but they have a manual work-around so still got good data. |
| data | Worked well. Litton is back and worked through whole flight |

**PRF04Y17 date 08/17/2017 day-of-week Mission Report**
*flight scientist: Sarah Doherty*
*ground scientist: Jens Redemann*

**Flight plan and objective**:

Radiation flight to capture RSP and 4STAR retrievals at high solar zenith angles.

- Best area was assumed to be near the routine flight track between 5 and 10S, where aerosol was supposed to increase steadily
- Mid- and high clouds were forecast to be minimal
- Looking for region with maximum low-cloud clearance

**Flight Summary:**

Transited on 5E to 9.0S, then headed east to find low-cloud-fraction region. At ~7E went south to 9.5S, then headed west.
Did a radiation wall between approx. 5.5E and 7W on 9.5S. This included, in order:

- High-altitude overpass of line where we'll do radiation wall
- Square spiral from ~6km to surface in mostly-cloudy conditions toward east end of wall (~6.6E)
- Above-cloud leg
- In-cloud leg
- Below-cloud leg
- Brief 2nd above-cloud leg for AOD measurement
- 3 vertically-stacked legs in the plume for aerosol in-situ measurements
- 2nd high-altitude overpass of radiation wall line
- Square spiral from ~6km to surface in clear conditions (a "hole" in the cloud cover), towards west end of wall (~5.9E)
- Short below-cloud leg, in-cloud legs and above-cloud legs in transit back to 5E line
- Short in-situ aerosol leg in-transit back along 5E line

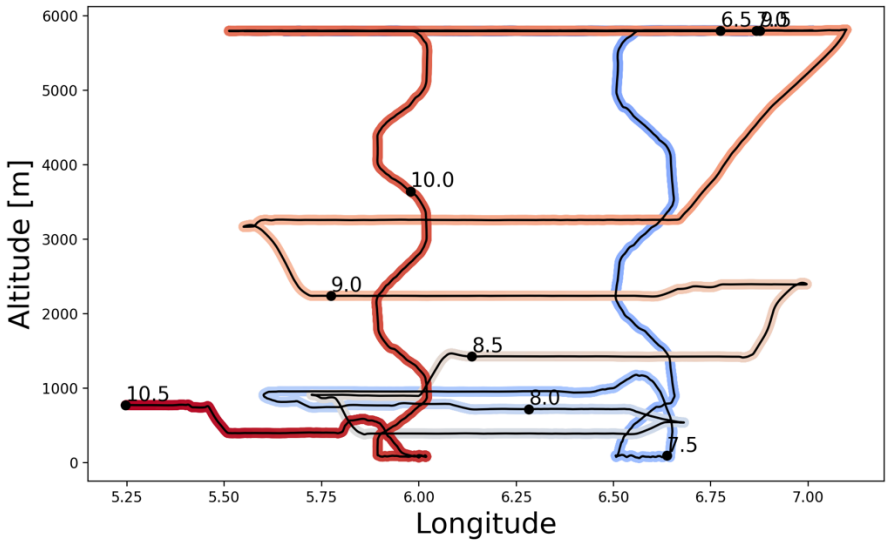
Boundary layer was the most polluted we've seen so far in ORACLES 2018. Cloud droplet number concentrations were accordingly elevated, in both the satellite retrievals and in the P3 cloud probe measurements. Based on chemical ratios from the aerosol in-situ measurements it also appeared to be a more aged plume than on other days in ORACLES 2018.

This will make a very good case for radiative closure, given the two square spirals in different conditions, the full radiation wall, and the moderate RH in the plume (which makes it easier to estimate the ambient-RH aerosol extinction from the low-RH in-situ scattering and absorption measurements).

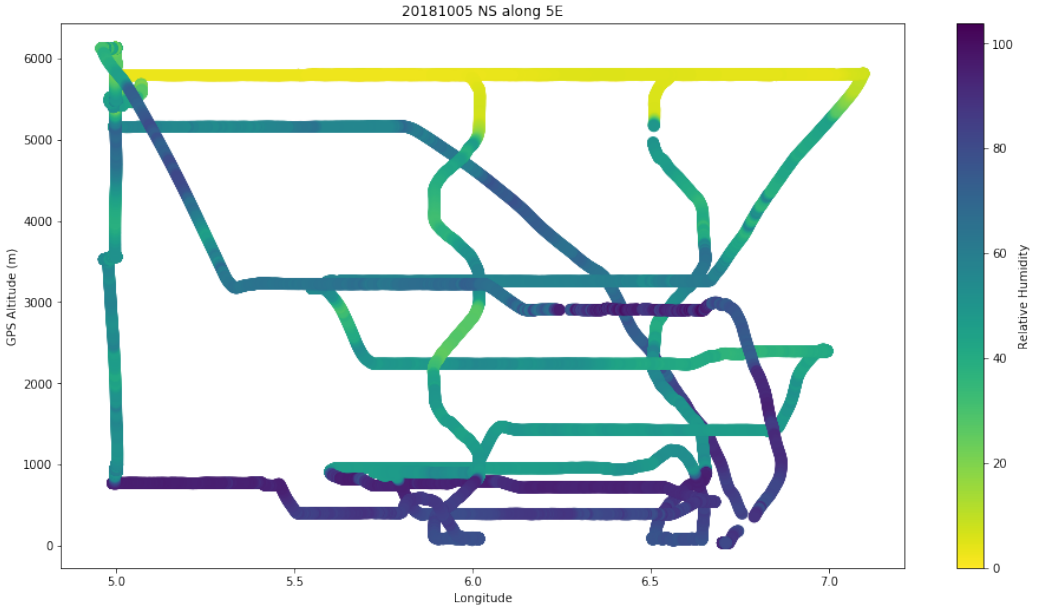
NOTE:

- Preliminary analysis indicates the aerosol measured on this flight was more aged than on other flights.
- Observed Kelvin-Helmholtz waves in top of aerosol layer on HSRL (e.g. see ~09:23-09:25UTC). Could also see this in 4STAR AOD variations.

Plot color-coded for time (UTC, labeled on line) while on radiation wall:




Plot showing RH as a function of longitude. This includes data from the entire flight, not just while on the radiation wall. During the in-situ aerosol legs RH appears to be ~50% for lower two legs and <70% for upper leg.

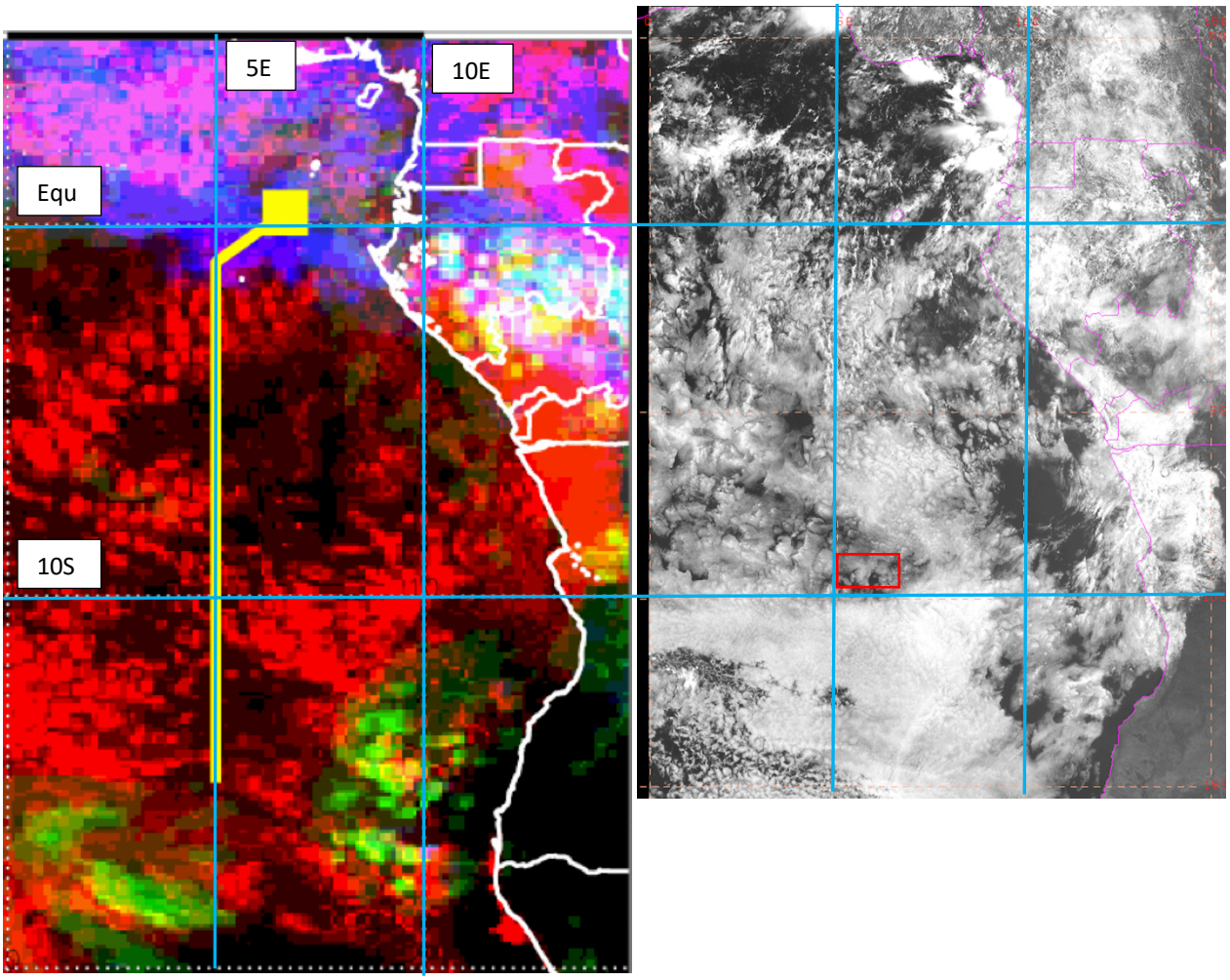


**Forecast Verification**:

**CLOUDS:**

45-hr forecast (Oct 04 weather/aerosol discussion) for 09:00UT Oct 5, 2018 shows a region of thin low clouds ~4-7S, 6-7E. As the day progresses, this region is forecast to move westward.

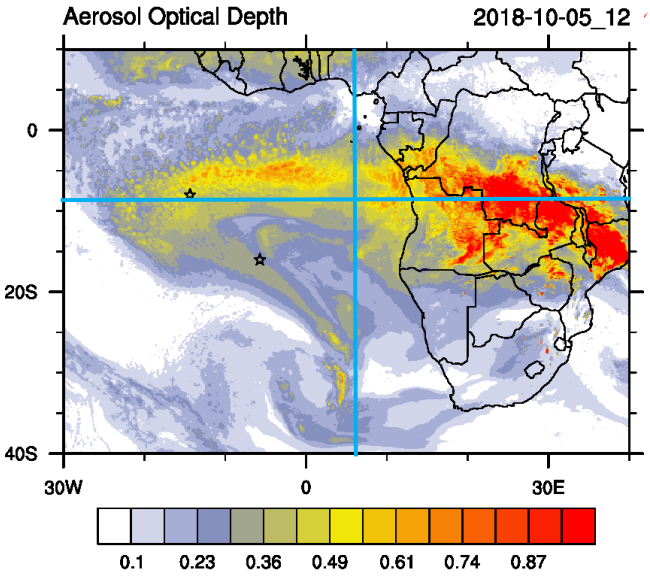
Forecast (left) and actual (right; high-res visible image) for 09:00 UTC. Clouds in 5-10E, 0-10S are broken in regions, but not as extensively as in the forecast. Approx. area of radiation wall shown as red box in vis. Image.



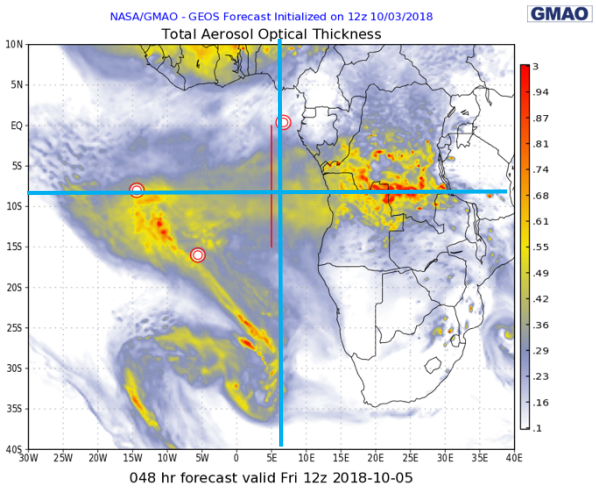
**AEROSOLS:**

48-hr forecasts for 05 Oct 12UTC.
Blue lines show 5E and ~9S – approx. location of Radiation Wall work:

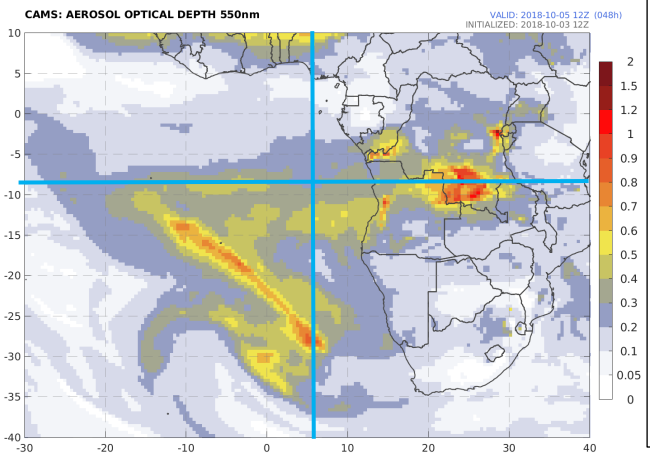
WRF-AAM




GEOS-5




CAMS




**AODs (approx) in Radiation wall study area:**

WRF-AAM: ~0.4-0.45

GEOS-5: ~0.45-0.5

CAMS: ~0.3-0.4

4STAR measured:

Above-cloud AOD ~0.3 (spiral #1)

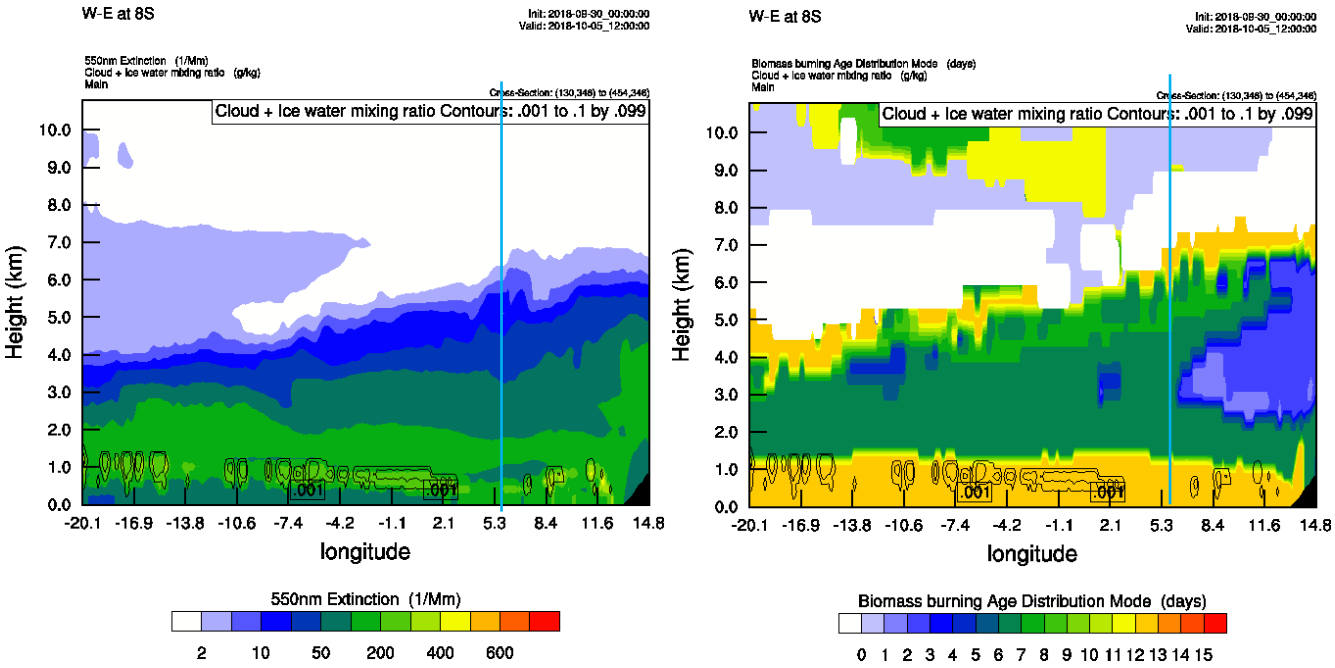
Total AOD: ~0.4 (spiral #2)

-

48-hr forecasts for 05 Oct 12UTC

WRF-AAM forecast plume height (top) and aerosol age distribution mode (bottom) along 8S.

Light blue lines mark approx 6E. Radiation wall was at 9.5S, 6E.

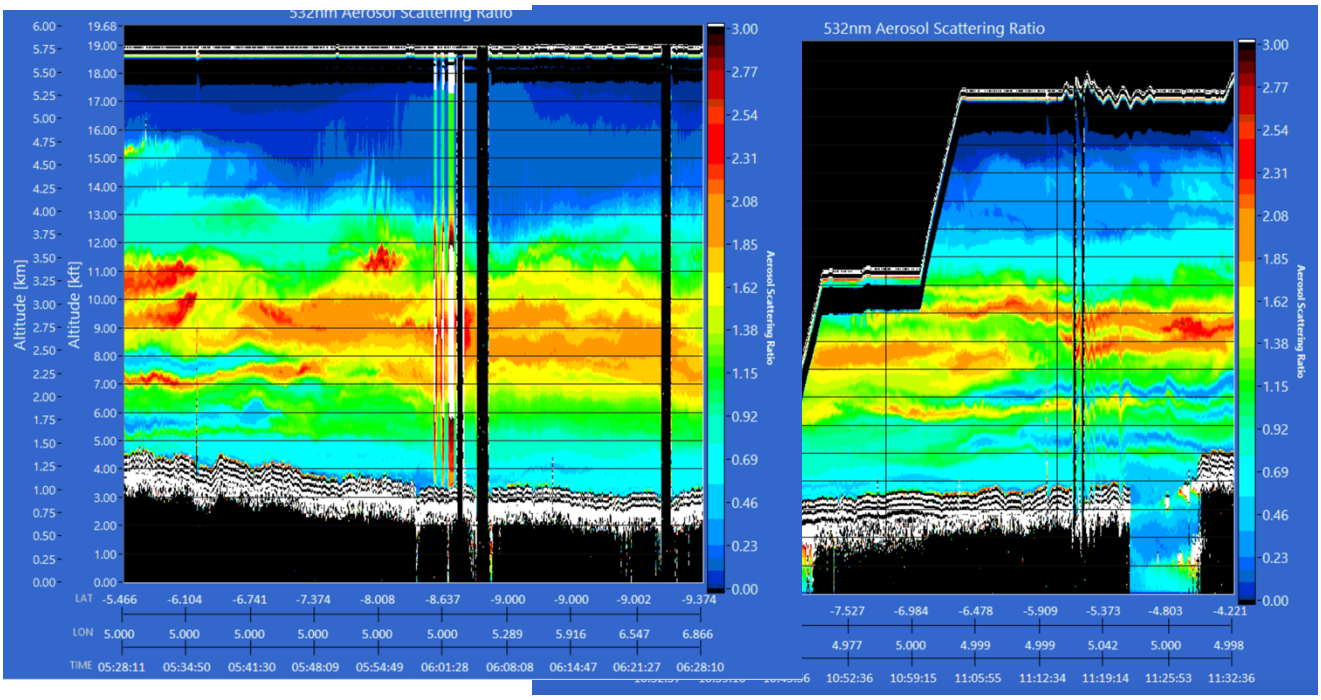



HSRL images on 5E line to 9S, then east-bound on 9S to 6.9E (left), before start of radiation wall;

And on 5E line from ~8S to 4S.

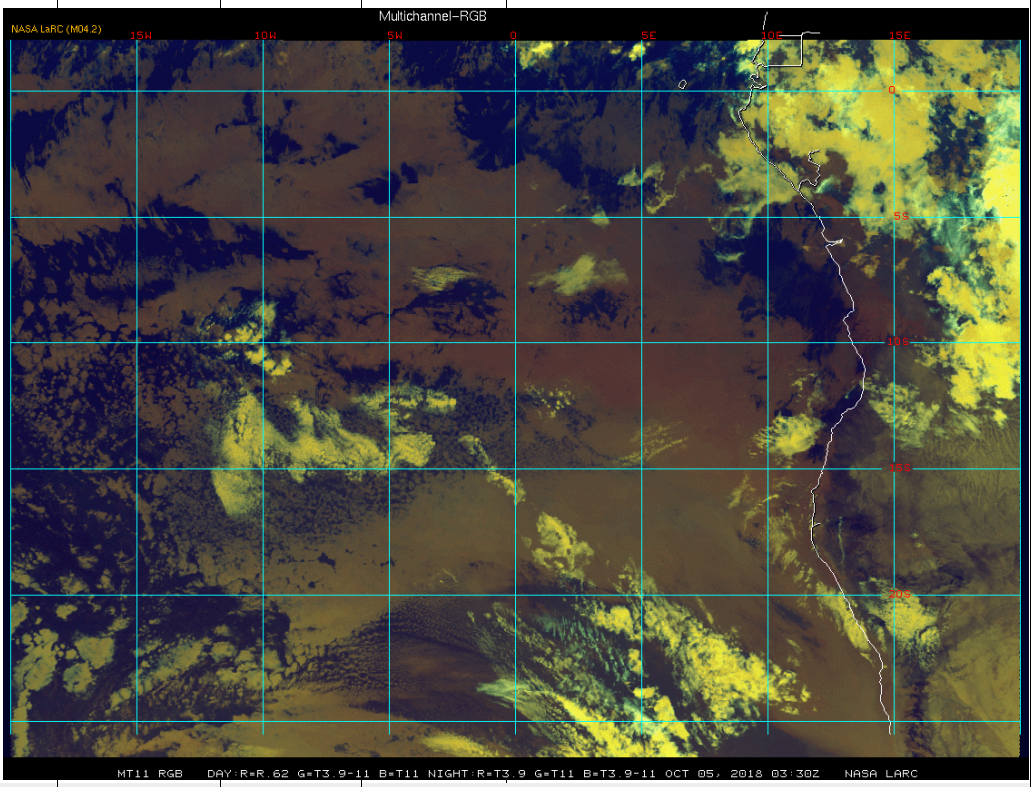
Plume is pretty consistently maximum 2.0-3.5km, whereas WRF-AAM has it mostly below 3km, and increasing from 3km to surface.

Based on in-situ data taken on the P-3, the plume was very aged, relative to on other days; WRF-AAM also shows a plume that is more aged that is typical (above, right).

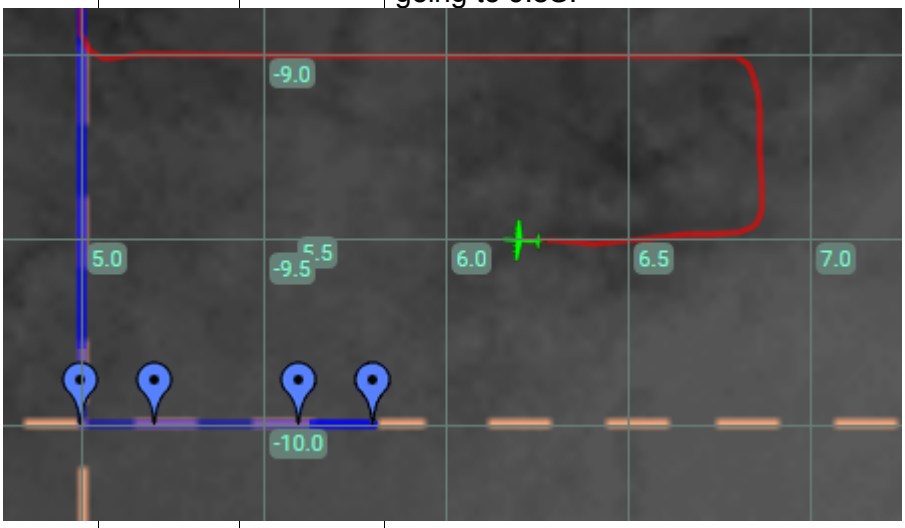


**Run Table [UTC]**

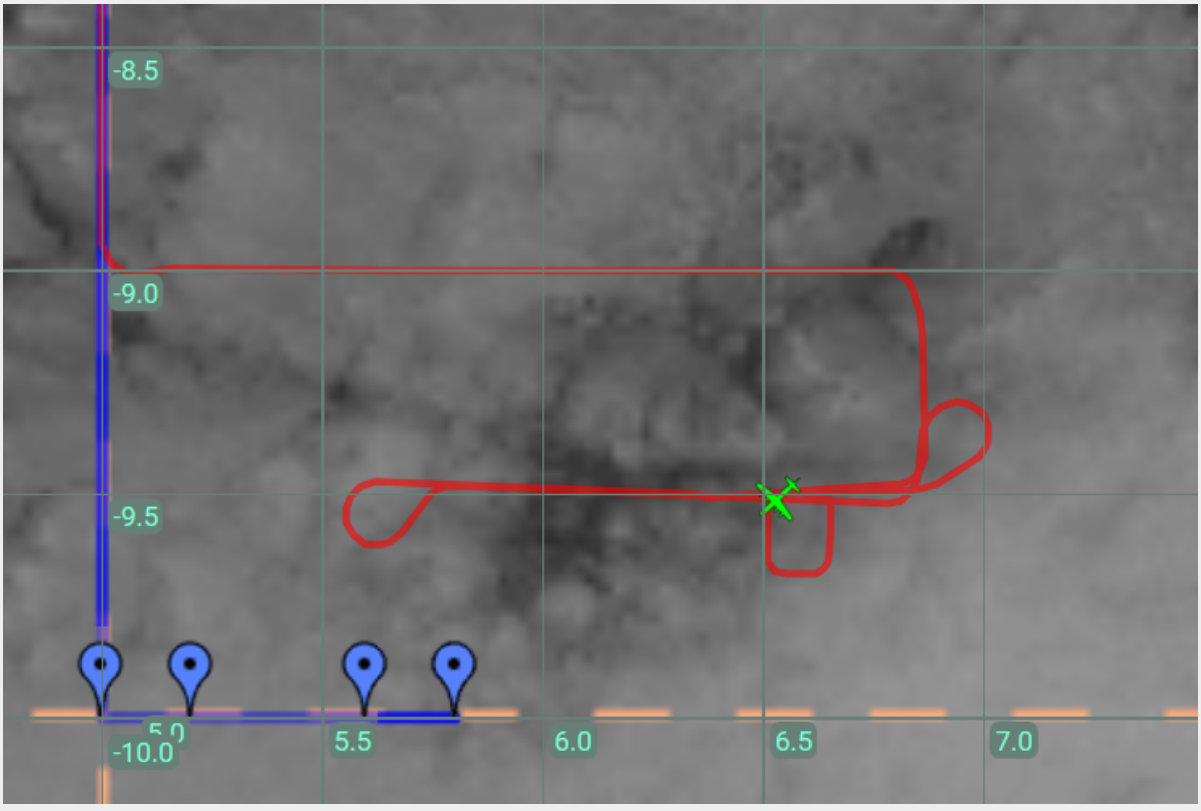
| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| Takeoff | 04:05 UTC | X | To max alt | take-off, mostly clear conditions<br>RGB image showing mid-level clouds (yellow) from 03:30 shown below. |
| Transit | 04:23 | | ~5.2km | Monitoring low cloud and mid-level clouds, best spot identified is 9S and 3-4E<br>Clean FT on HSRL and drizzling clouds below |
| Transit | 04:36 | | ~5.2km | Right at equator starting to see a bit of an aerosol layer at 6-7k'/2km. |
| Transit | 04:39 | 04:50 | ~5.2km | Clouds lightly precipitating then raining ~1mm/hr (a lot for ORACLES) at 0deg 50' S (4:39UT) & again at 1.6S (04:47UT). At 2S it was up to a few mm/hr (04:50UT), where HSRL cloud tops were at 1.75-2km. |



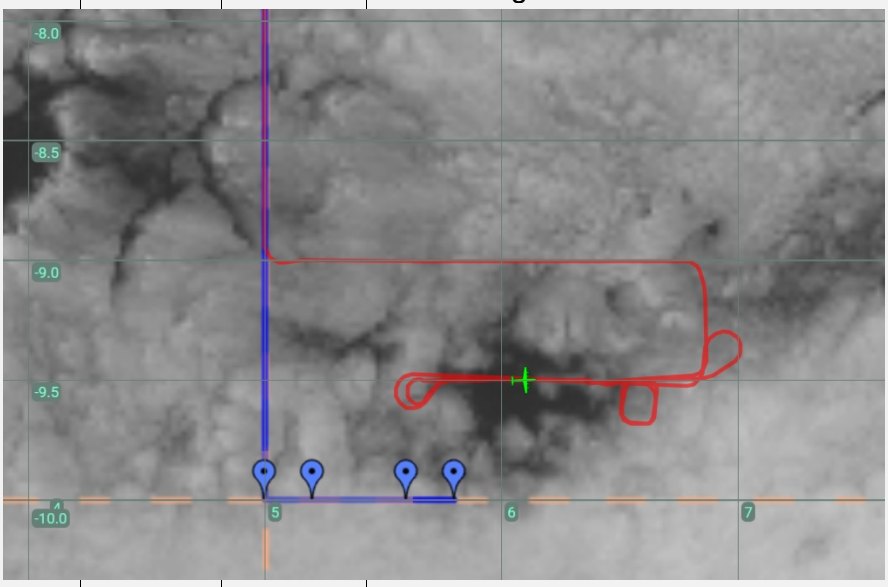
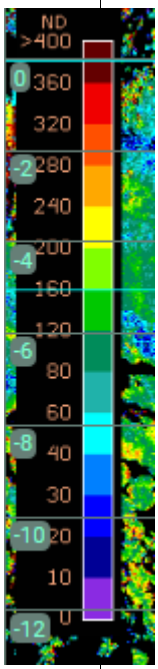
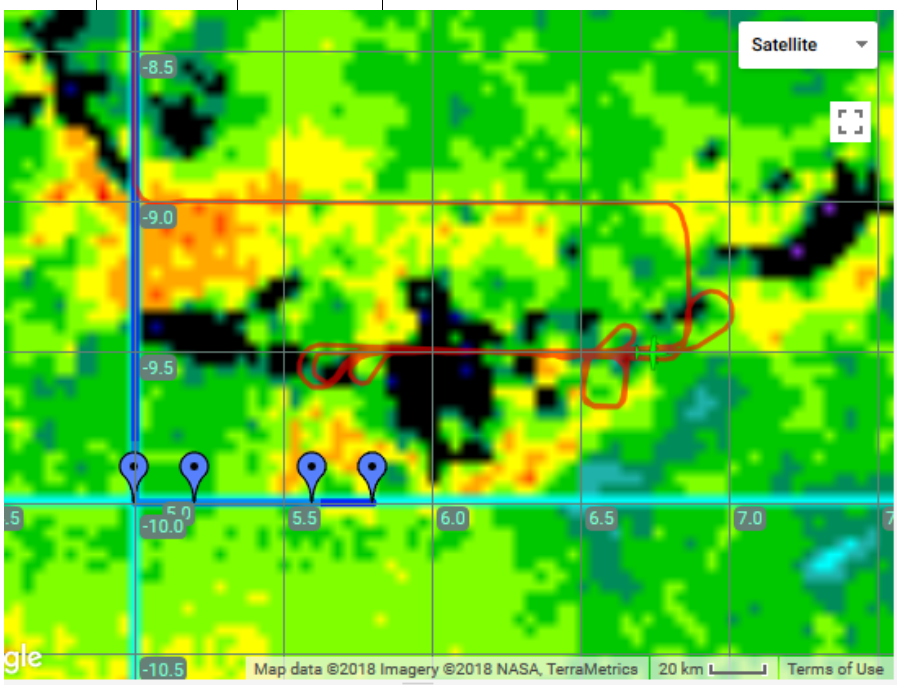
| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| Transit | 05:10 | | ~5.8km | 3.76S: flying over mid-level cloud; lower level cloud deck “much less active” (APR)<br>Cloud top altitude has dropped to ~4,000’, 1.25km along with appearance of mid-alt clouds |
| Transit | 05:15 | | 5.8km | ACAOD slowly increasing towards 5S along routine track, up to 0.25 now per HSRL. |
| Transit | 05:30 | | 5.8km | 5.7S: precip. went from borderline detectible to detectible to wide-spread drizzling. No cloud height change on HSRL |
| Turn | 06:05 | | 5.8km | 5E, 9S turning E shooting for semi-clearing patch on IR imagery. |
| High-altitude leg exploring for broken clouds | 06:05 | 06:25 | 5.8km | East-bound leg on 9S from 5E to 6.8E. Been in quite solid clouds so trying to nudge south half a degree to find more broken cloud. Turned at ~6.7E; going to 9.5S. |
| High-altitude leg exploring for broken clouds | 06:25 | 06:30 | 5.8km | South-bound from 9S to 9.5S on ~6.8E |
| West-bound high-alt. | 06:30 | 06:43 | 5.8km | Turn to head west-bound on 9.5S. |



| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| leg over rad. wall area | | | | Decided to do wall on 9.5S between approx 6.25deg and 5.65degE |
| Turn | 06:43 | 06:48 | | West-bound to east-bound at 5.55E |
| West-bound high-alt. leg over rad. wall area | 06:48 | 06:57:30 | 5.8km | East-bound high-altitude overpass of radiation wall area, 5.8E – 6.8E on 9.5S. Includes overshoot of square spiral location for RSP. |
| Turn | 06:57:30 | 07:04 | 5.8km | East-bound to west-bound |
| East-bound high-alt. leg back to rad. wall area | 07:04 | 07:08 | 5.8km | West-bound transit to square spiral location |
| | 7:15 | | | Radiation wall screen grab from MTS |

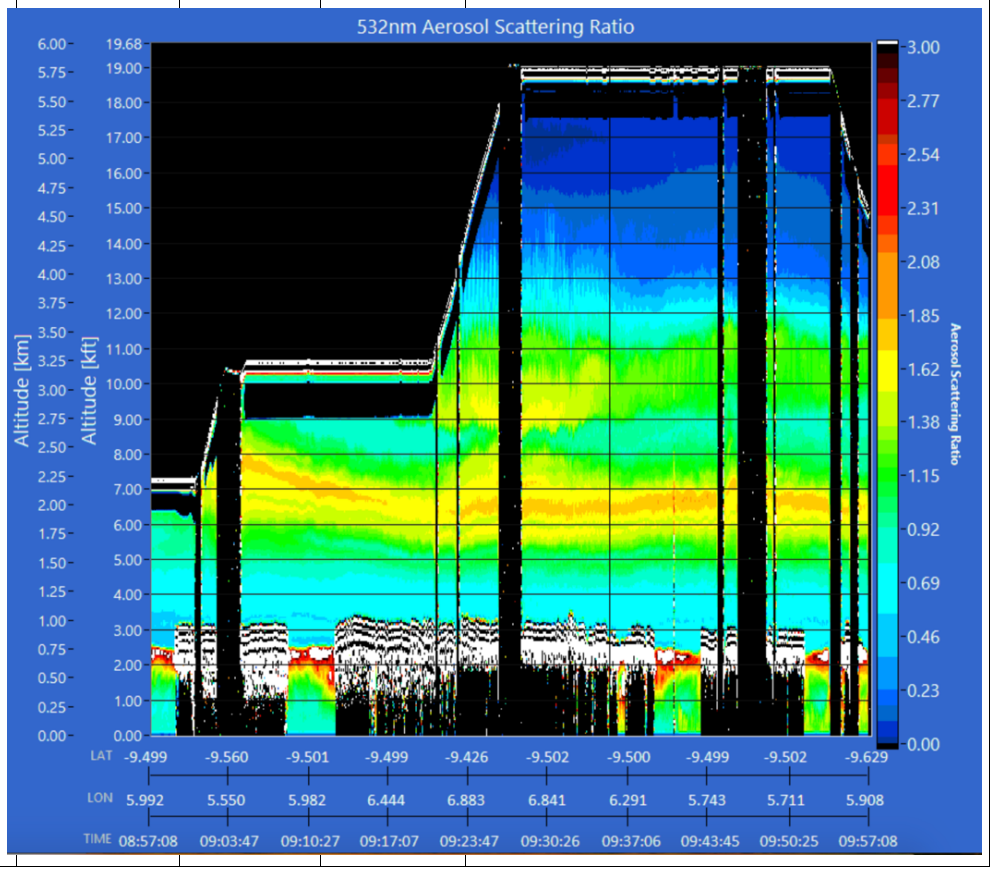


| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| SQUARE SPIRAL #1 | 07:08 | 07:27 | 5.8km to 80m | Square spiral down.<br>Hit cloud top at 2787' press alt<br>ACAOD = 0.31<br>Definitely still have aerosol<br>Clouds not precipitating<br>RH decreased below plume (where it was low: ~50%) |
| Spiral back up to above-cloud | 07:27 | 07:34 | 80m to 980m then 950m | At surface:<br>SP2 counts at ~350ng BC mass<br>Picking up some of Rose's large particles<br>Amie is seeing organics 500-800ng<br>Absorption ~10$Mm^{-1}$<br>SSA~0.8 w/out PSAP 20% correction etc.<br>Particles activating at lower levels as go down in aerosol.<br>07:32 popped above cloud at 3200' press alt<br>07:33 dropping down a touch |
| ABOVE-CLOUD LEG (west-Bound) | 07:34 | 07:47:30 | 950m | 200'-above-cloud leg west-bound 6.5E – 5.65E<br>07:40 hitting low cloud breaks start at 6.15S<br>Scattering above and below cloud almost exactly the same<br>BC and organics about twice above cloud than below cloud<br>4STAR got sky-scans: ACAOD ~0.3 with some variation; highest AOD in middle of the leg |
| Turn & decend | 07:47:30 | 07:52 | | |
| IN-CLOUD LEG (east-bound) | 07:52 | 08:04 | 770m | Most polluted cloud this year.<br>HiGEAR on CVI: 40nm particles in cloud droplets; not seeing much in the way of 30nm particles.<br>Clouds very broken & thin with clear patch opening up.<br>Mode of cloud particles ~20-30 according to cloud probes; $R_{eff}$ ~10.<br>07:57 UTC screen grab below from in-cloud leg |

| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| | 07:57 | | | MTS screen grab at 07:57, while on in-cloud leg  |
| | | | | SEVIRI cloud drop number retrievals indicate polluted clouds near radiation wall location, but less polluted clouds just South. (See additional image at end of flight report)   |

| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| Turn & ascend | 08:04 | 08:09 | | Turning and ascending to do 2min above-cloud leg from east end of wall. |
| BELOW-CLOUD LEG (west-bound) | 8:09 | 08:20 | 390m | BL dirty along entire track.<br>Leg 6.6 to 5.85E. |
| Climb west-bound to above-cloud, then turn to east-bound | 8:20 | 08:25:15 | | |
| 4STAR | 08:25:15 | 08:27:45 | | East-bound, above-cloud, at west end of radiation wall. 5.83E to 5.99E. |
| Climb for first In-situ aerosol leg | 08:27:45 | 08:30 | | East-bound climb |
| IN-SITU AEROSOL LEG #1 | 08:30 | 08:39:50 | 1.4km /<br>4400’ | East-bound: 6.1 to 6.8E<br>CO 190-210BC=900ng/cm^3<br>Org = 4ug<br>Green scatter ~40Mm<br>Low SSA …<br><br>1knot cross-wind out of S/SW at 4600’ - ! so totally calm<br><br>AOD 0.28 with small oscillations (“non-normal” according to Sam; maybe related to oscillations in HSRL) |
| Ascend & turn | 08:39:50 | 08:44 | | Ascend east-bound, then turn to west-bound |
| IN-SITU AEROSOL LEG #2 | 08:44 | 09:00:30 | 2.4km->2.2km /<br>7,400’ ->6,900’ | West-bound<br>08:44-08:49 7E-6.6E at 2.4km<br>08:49-09:00 6.6-5.7E at 2.2km<br>Had to do some adjusting down in alt to find max in aerosol conc.<br>Concentrations increased along leg.<br>At ~3/4 through leg:<br>Green scattering initially ~85, now up to ~100Mm-1<br>Scattering angstrom ~2<br>CO Initially ~250 ppbv then rose to ~270ppb<br>BC 1.3ug/$m^3$ initially; then 1.5ug/$m^3$ |

| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| Ascend & turn | 09:00:30 | 09:05 | | Ascend west-bound; turn to east-bound. |
| IN-SITU AEROSOL LEG #3 | 09:05 | 09:20 | 3.25km / 10,050’ | East-bound: 5.7 to 6.7E |
| Ramped ascent then turn | 09:20 | 09:29 | | Ascend east-bound then turn |
| HIGH-ALT OVERPASS of Radiation wall area | 09:29 | 09:44 | 5.8km / 18,000’ | East-bound: 7.0 to 5.7E<br>4STAR AOD~0.08 – dirty window<br>09:32:45 at east edge of square spiral<br>Aerosol looks more 2-layered than on first run. Maybe the upper layer dried out? HSRL AOD just shy of 0.4 |
| Turn west- to east-bound | 09:44 | 09:53:45 | 5.8km / 18,000’ | Return to clear-sky spot along the wall for a 2nd spiral.<br><br>Aerosol layers and gaps in clouds allowing for BL retrievals from HSRL: |



| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| SQUARE SPIRAL #2 | 9:53:45 | 10:13 | 5.8km -><br>80m | Square spiral at 9.5S/6E.<br>12,000' press alt to 12,600' press alt BC, org, scatt all starting to go up. Scat at 18$Mm^{-1}$<br>9,000' GPS alt aerosol leveled off at green scat 53$Mm^{-1}$ & BC also leveled off. OA & scattering lower than in first spiral. RH peaked in highest aerosol layer in mid-60's.<br>At 5700' ~50% RH<br>Rose has been seeing her large particles since ~9,000'<br>Top of BL a bit higher on this end (vs. east end of wall where did 1st spiral)<br>AMS indictes BL even a bit more polluted than first BL leg. But SP2 looks about the same. Art says maybe a tad higher (~10ng)<br>CO ~105ppbv<br>Winds 8knots at 235deg<br>Steve says he's not seeing a Hoppel minimum so not cloud-processed. Same in first BL leg.<br>Sam reported AOD ~0.4 at surface. |
| Turn at surface | 10:13 | 10:17 | | Circle at surface |
| Climb to just Below cloud | 10:17 | 10:20 | | Initially to 580m then down to 400m |
| BELOW-CLOUD LEG in transit to 5E from radiation wall area. | 10:20 | 10:26 | 400m | Exited from south edge of square spiral at 200' for NW heading to 5E.<br>Went from clear sky to just under cloud at ~10:21<br>Below-cloud leg for SSFR in transit from wall area to 5E line, heading NW.<br>→ During Terra overpass time |
| Ascent | 10:26 | 10:27 | 400-><br>740m | Ascent in-transit from 9.3S, 5.5E to get in cloud |

| description | beginning time | end time | altitude | notes |
|---|---|---|---|---|
| IN-CLOUD LEG | 10:27 | 10:38 | 770m / 2,300’ | Popping in and out of small clouds.<br>HiGEAR on CVI.<br>CO has gone from ~104 to ~110 when went from more broken clouds to more consistent low clouds.<br>Mode of ~18microns on PDI. Really small droplets.<br>Ended leg when came out of them horizontally. |
| ABOVE-CLOUD 4 STAR SKY-SCANS | 10:39 | 10:44:30 | 935m / 2,800’ -> 1,000m / 3,100’ | Above-cloud legs for 4STAR sky-scans.<br>Bumped up ~100’ between 2 4STAR sky-scans to stay above cloud. |
| Ascend for aerosol leg | 10:44:30 | 10:50 | | |
| IN-SITU AEROSOL LEG | 10:50 | 10:59:45 | 3.5km / 10,800’ | In-transit on way home:<br>5E, 7.7S – 6.9S |
| Ascend to high altitude | 10:59:45 | 11:05 | | 5E, 6.9 – 6.5S |
| High-altitude leg on transit back to TMS. | 11:05 | 12:20 | 5.5 km / 17,000’<br>Then to 6.1km / 18,000’ | 5E, 6.5 – 0S<br>High alt leg for HSRL & RSP.<br>But RSP got messed up by plane wiggles.<br>Changed to fully manual flying so had ~20min leg ending at 0S,5E that was good for RSP.<br>Simone/APR says precip rates here (N of 1.5S) very similar to the morning.<br>1-3mm/hr rain.<br>Sees 4 layers of clouds… |
| RTB via 0S, 5E | 12:20 | 12:54:50 | | |
| LANDING | 12:54:20 | X | | |

**Other Visuals:**

09:00 UTC Cloud Droplet Number Concentration from LARC ORACLES MSG cloud products.

Thick cyan lines show ~6E and ~9.5S = radiation wall area, highlighting elevated Nd.